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UK CL (Edition M ) B3C C1B6D , E1F FCJ FLA

INT CL<sup>5</sup> E21B

## (54) Rotary downhole cutting tool

(57) A downhole cutting tool in which a body 10 has a cylindrical sidewall and an axial cavity 20 formed therein, and an axial channel 92 communicates the cavity 20 with the exterior at the lower end of the body 10. A plurality of equally spaced longitudinal slots 52a, b, c, are formed through the body sidewall in communication with the cavity 20 and each has a cutter bar 66a, b, c, having a vertical cam surface on the inner edge and is pivotally affixed for radial movement within the respective slot. A pressure operated piston 58 is slidable in the cavity 20 in response to fluid pressure to urge against the cam surfaces and force the cutter bars radially outwardly into cutting engagement with the ground.

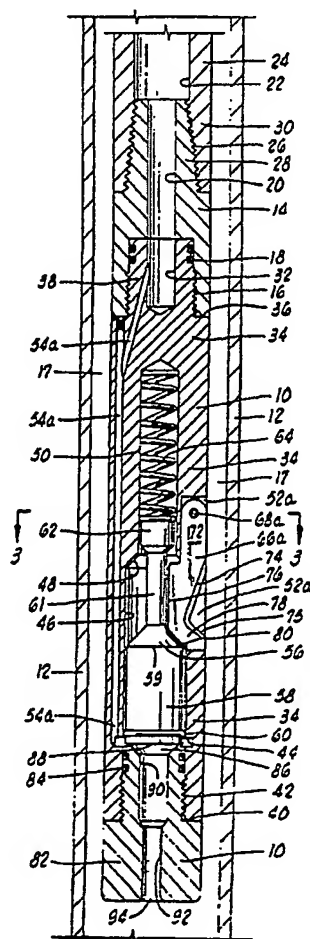


FIG. 1

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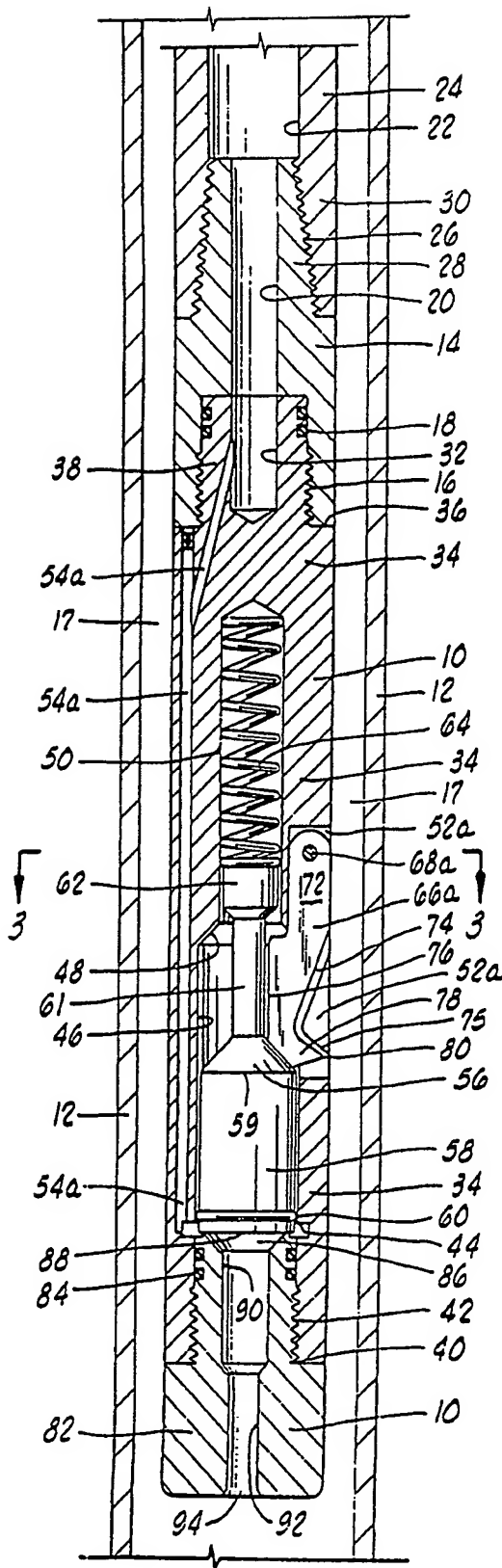


FIG. 1

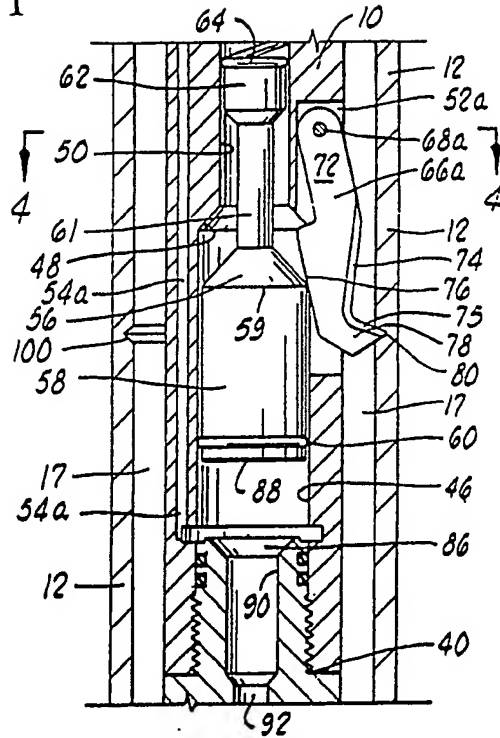


FIG. 2

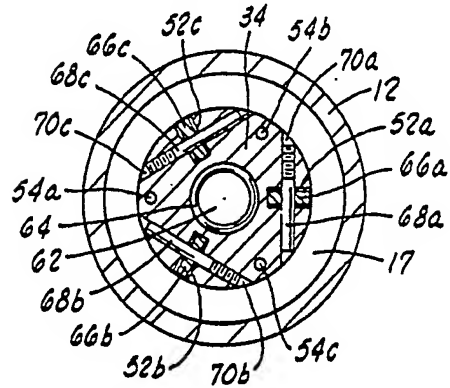


FIG. 3

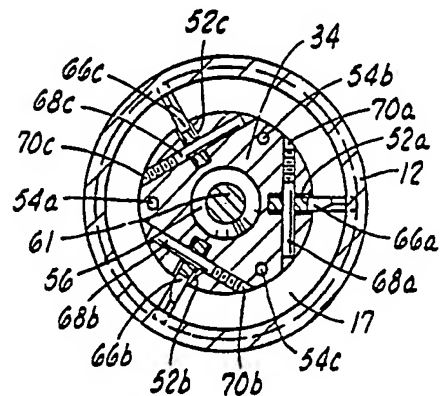


FIG. 4

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## ROTARY DOWNHOLE CUTTING TOOL

5 This invention relates generally to downhole cutting tools and more particularly, but not by way of limitation, it relates to an expandable cutting tool that may be suspended via continuous tubing or the like for rapid cutting of borehole casing, drill pipe, tubing liner, etc.

10

There have been developed a number of different types of downhole rotary tools for scraping, cleaning and cutting tubular goods in a borehole. Tools of this general type must necessarily be of smaller diameter  
15 suitable for lowering through a relatively narrow diameter casing or tubing string to carry out cleaning and cutting operations. "Through tubing" clean-out tools as used for clean-out, cable cutting, tubing cutting and the like, have been developed and distributed by Kat  
20 Tool, Inc. of New Iberia, Louisiana.

The closest prior art may well be within the applicant's own prior development activity as characterized by U.S. Patent No. 4,809,793, issued on March 7, 1989, and a co-pending United States patent application which is  
25 scheduled to issue on April 13, 1993 as U.S. Patent No. 5,201,817.

The present invention relates to a still further improved downhole cutting tool wherein plural cutter  
30 blade actuation is effected more positively to enable

more rapid and accurate cutting of casing, drill pipe or the like. The tool consists of an elongated, cylindrical body member that is adapted for subassembly usage with various forms of stabilizer, rotational motor, etc. as  
5 suspended to cutting depth or position by means of such as a tubing link, either continuous or jointed. The body member includes a plurality of equi-spaced, longitudinal slots formed through the body member sidewalls and in communication with an internal axial cavity disposed  
10 within the body member. A spring loaded piston is slidably positioned within said cavity with an upper annular shoulder positioned to urge each of respective cutter members radially outward in response to applied fluid pressure urging the piston member upward thereby to  
15 continually force the cutter members outward.

Therefore, it is an object of the present invention to provide a rotary downhole cutting tool that effects positive, rapid response to effect an inside out cutting operation.

20 It is also an object of the present invention to provide a rotary cutting tool that utilizes relatively fewer components.

It is yet further an object of the invention to provide a downhole cutting tool that is lightweight and  
25 easily manageable at or about a drilling site.

Finally, it is an object of the present invention to provide a rotary cutting tool that is usable for operation over a range of pipe inside diameters with equal cutting capability and speed.

30 Other objects and advantages of the invention will be evident from the following detailed description when read in conjunction with the accompanying drawings that illustrate the invention.

Figure 1 is a vertical cross section of the present invention as positioned in a well bore;

Figure 2 is a portion of the Figure 1 vertical section when the rotary tool is in mid-actuation;

Figure 3 is a cross-section taken on lines 3-3 of Figure 1; and

Figure 4 is a cross-section taken on lines 4-4 of Figure 2.

10

Figure 1 shows a rotary cutting tool 10 as suspended downhole in a well casing 12 preparatory to a cutting operation. The rotary cutting tool 10 is threadedly received in a connector sub 14 by means of a threaded insert 16 and sealing O-rings 18. An annulus 17 is defined adjacent the inner wall of casing 12. The connector sub 14 has an axial void 20 which communicates with an axial channel 22 of a rotary motor sub 24 joined by threaded coupling 26 which is formed between pin insert 28 and collar 30.

20

The rotational motor sub 24, a motor selected for small diameter drilling operation, is commercially available from SlimDril, Inc. of Houston, Texas. The small diameter SLIMDRIL™ motors are capable of generating bit speeds from 740-1230 RPM for 1 11/16 outside diameter and a range of from 400-800 RPM at an outside diameter of 3 3/4 inches. In practice, the rotational motor sub 24 would normally be connected to a supporting member such as a continuous tubing string through which drilling fluid downflow is conducted through axial passages 22 (motor sub 24) and 20 (connector sub 14) for introduction via axial bore 32 of a tool body member 34. In the case

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of a jointed tubing string, the motor sub may not be required.

The body member 34 is formed as an elongated, cylindrical member having an upper annular shoulder 36 which is formed into the cylindrical end portion 38 having threads 16 formed thereon. The lower end of body member 34 has a cylindrical bore 40 formed axially therein with threads 42. The cylindrical bore 40 communicates with an annular channel 44 adjacent a cylinder bore 46 which terminates upwardly in a shoulder 48 and smaller diameter bore 50. A plurality of longitudinal slots 52a, b and c (see also Figure 3) are formed in equi-spacing around body member 34, each communicating with the upper portion of cylinder bore 46. In this case, three such longitudinal slots are shown, however it could be any of several pluralities so long as the circumferential positions are in balanced relationship. Between each of the longitudinal slots 52a, b and c are formed down flowing ports 54a, b and c which communicate and direct drilling fluid between upper end cavity 32 and the lower annular cavity 44.

A reciprocal piston member 56 is unitarily formed with a piston 58 having a sealing ring 60 in contact with cylindrical wall 46, and having an annular shoulder 59 while extending a rod 61 and foot 62 into contact with a heavy compression spring 64 located within the upper cylindrical cavity 50. A cutter bar 66a, b and c is suspended in each of longitudinal slots 52a, b and c by means of respected pivot pins 68a, b and c which are threadedly secured through arc segment holes 70a, b and c in body member 34. Each of cutter bars 66a, b and c is similarly shaped and of the same thickness to have an upper pivot stem 72 extending into a lower portion having a cutting blade 74 extending through an inward angle, and

a rear straight-edged camming surface 76 extending downward to form a hook-shaped foot member 78. The foot member 78 terminates outward in a point 80 that provides initial cutting contact, as will be further described.

5 Each of the cutter bars 66a, b and c is formed of process hardened steel with selected tactile areas, such as cutting edge 74 and foot point 80, including additional hardening structure such as flush-mounted diamond pads or alternatives such as inlaid configurations of tungsten

10 carbide surface such as KUTRITE® and/or thermally stable polycrystalline diamond materials within suitable matrices.

The lower end of body member 34 is closed over by a lower end cap 82 threadedly secured within end bore 40 by

15 means of threads 42 as sealing rings 84 provide fluid-tight fixture. Lower end cap 82 defines an upper angular bore 86 beneath the bottom 88 of piston 58 for communication with annular groove 44 and the drilling fluid supply source. Angular bore 86 then leads down into a

20 cylindrical counterbore 90 and still further reduced cylindrical bore 92 to bottom port 94 which releases spent drilling fluid.

In operation, after a cutting decision has been finalized, the rotary drilling tool 10 is prepared at the

25 surface by connection of the necessary subs and the suspending tubing, either continuous or sectional. The triangular array of cutter bars 66a, b and c are positioned at their innermost disposition as shown in Figure 1, with compression spring 64 fully extended in its

30 uncompressed attitude, and with the piston member 58 seated in its fully downward position with piston base 88 and sealing ring 60 adjacent the annular groove 44. The rotary cutting tool 10 can then be entered down the bore-hole as suspended by tubing (not shown) until indication

of the arrival of rotary cutting tool 10 at the proper cut position along casing 12.

Drilling fluid under pressure is then applied down through the tubing which causes initial rotation of the rotational motor sub 24 and rotary cutting tool 10 as drilling fluid progresses down through axial void 22 and bore 20, and through each of ports 54a, b and c to the annular groove 44 with release of drilling fluids through lower port 94. As drilling fluid pressure builds up, according to how rapidly the pressure build-up is applied from the surface source, a pressure increase within angular bore 86 and annular groove 44 forces the piston member 58 upward through the attitude as shown in Figure 2. As this occurs, and the drilling fluid pressure at angular bore 86 approaches maximum, the annular cam shoulder 59 urges against cam edge 76 of respective cutter blades 66a, b and c to urge the cutter radially outward and into engagement with the inner wall of casing 12. As illustrated, the rotation of cutter point 80 causes formation of a cut 100 in the casing inner side wall and, in accordance with the amount of applied drilling fluid pressure and proportional rotary speeds, the cutter point 80 cuts rapidly through the casing to complete the cut. The completed cut will be indicated by a rapid pressure variation at the surface.

After noting a pressure indication of casing severance, surface fluid pressure is reduced to allow components of the rotary tool 10 to reposition to their relaxed or quiescent state, as shown in Figure 1, whereupon the rotary cutting tool 10 may be reclaimed at the surface with commencement of subsequent well activity.

The foregoing discloses novel rotary cutting tool structure that enables rapid and accurate downhole cutting of casing, drill pipe and the like. The cutter



blades effect a square casing cut with minimal surface degradation and the cuts are made in much reduced time than has heretofore been attainable.

5 Changes may be made in the combination and arrangement of elements as heretofore set forth in the specification and shown in the drawings; it being understood that changes may be made in the embodiments disclosed without departing from the scope of the invention as defined in the following claims.

10 What is claimed is:

CLAIMS

1. A downhole cutting tool, comprising:  
a source of fluid pressure;  
5 a body member having a cylindrical sidewall with upper and lower ends, and having an axial cavity formed therein with said cavity communicating externally at the lower end of the body member;  
10 plural equi-spaced, longitudinal slots formed through the body member sidewall in communication with said cavity;  
plural cutter bars having vertical cam surfaces on the inner edge and being pivotally  
15 affixed for radial movement within respective ones of the plural longitudinal slots; and  
piston means slidable in said cavity and actuatable upward in response to said fluid pressure to urge against said cam surfaces and  
20 force said plural cutter bars radially outward into cutting engagement.
2. A downhole cutting tool according to claim 1, wherein said plural cutter bars each comprise:  
25 a pivot stem having upper and lower ends and including a pivot hole at the upper end;  
a linear camming surface extending from the pivot stem lower end facing radially inward;  
a cutting blade extending from the pivot stem  
30 lower end facing radially outward; and  
a hook-shaped foot member extending from said cutting blade and camming surface, to extend radially outward to terminate in a point.
- 35 3. A downhole cutting tool according to claim 1 or 2, wherein said piston means comprises:  
a piston having an upper camming shoulder and

extending a piston rod upward therefrom; and  
a compression spring disposed over said  
piston rod to maintain downward spring pressure.

- 5 4. A downhole cutting tool according to claim 1, 2 or  
3, which is further characterized to include:

at least one port extending down through said  
body member from the upper end to the lower end in  
communication with said cavity; and

10 means connecting said fluid pressure to the  
body member upper end.

5. A downhole cutting tool according to any preceding  
claim, which is further characterised to include:

15 support means secured to said body member  
upper end for suspending the cutting tool in a  
borehole, said support means conducting fluid  
under pressure to said body member upper end; and

20 at least one port connecting from said body  
member upper end to the lower end to a point  
beneath said piston means.

6. A downhole cutting tool according to claim 5,  
wherein:

25 there are three such ports disposed in equi-  
spaced circumferal location; and

there are three longitudinal slots with  
cutter bars pivotally affixed therein.

- 30 7. A downhole cutting tool according to any preceding  
claim, wherein said plural cutter bars each comprise:

a generally flat, elongated cutter bar having  
a pivot hole at the upper end and extending  
downward to expose a linear camming surface at the  
35 lower, radially inward edge, while the radially  
outward edge is formed as a cutter blade extending  
into a hook and point portion; and

hardening inlays positioned at primary right turn contact positions of the cutter bar.

8. In a downhole cutting tool of the type that is suspended by fluid conducting tubing and responsive to increased fluid pressure to effect a tubular goods cutting operation, the apparatus comprising:

an elongate body of revolution having a sidewall, upper end and lower end with the upper end connected to said tubing, said body having an axial cylinder cavity disposed adjacent the lower end;

plural, equi-spaced longitudinal slots formed radially to extend outward from the cylinder cavity through the body sidewall;

plural, cutter bars pivotally suspended in each of said plural longitudinal slots, each cutter bar having a cutter blade and point at the outer, lower extremity with a generally flat camming surface at the inner side;

a piston member disposed slidably in the lower portion of the body axial cylinder cavity; and

porting means in said body of revolution directing fluid under pressure from the body upper end down to the body lower end for release below the piston member to force the piston member upward while urging against the plural cutter bar camming surfaces thereby to force the cutter bars outward into cutting contact with surrounding tubular goods.

9. Apparatus according to claim 8 wherein:

there are three such cutter bars and longitudinal slots.

10. Apparatus according to claim 8 or 9, which is

further characterized to include:

an annular groove formed at the lower end of the axial cylinder cavity of the body of revolution adjacent the piston member; and

three of said porting means directing flow between the body upper end down for release at the annular groove.

11. apparatus according to claim 8, 9 or 10, wherein said plural cutter bars each comprise:

a generally flat, elongated cutter bar having a pivot hole at the upper end and extending downward to expose a linear camming surface at the lower, radially inward edge, while the radially outward edge is formed as a cutter blade extending into a hook and point portion; and

hardening inlays positioned at primary right turn contact positions of the cutter bar.

12. A downhole cutting tool substantially as hereinbefore described, with reference to, and as illustrated in the accompanying drawings.

**Examiner's report to the Comptroller under Section 17  
(The Search report)**

GB 9410459.3

**Relevant Technical Fields**

(i) UK Cl (Ed.M) E1F (FCJ, FLA); B3C (C1B6D)

(ii) Int Cl (Ed.5) E21B

Search Examiner  
D J HARRISON

Date of completion of Search  
11 AUGUST 1994

**Databases (see below)**

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Documents considered relevant  
following a search in respect of  
Claims :-  
1 TO 12

**Categories of documents**

- |                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                           |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>X:</b> Document indicating lack of novelty or of inventive step.</p> <p><b>Y:</b> Document indicating lack of inventive step if combined with one or more other documents of the same category.</p> <p><b>A:</b> Document indicating technological background and/or state of the art.</p> | <p><b>P:</b> Document published on or after the declared priority date but before the filing date of the present application.</p> <p><b>E:</b> Patent document published on or after, but with priority date earlier than, the filing date of the present application.</p> <p><b>&amp;:</b> Member of the same patent family; corresponding document.</p> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Category	Identity of document and relevant passages		Relevant to claim(s)
X, P	GB 2262758 A	(HAILEY) 30 June 1993 see piston 72, Figure 3	1, 2, 4, 5, 8
X	US 4893675 A	(SKIPPER) whole document	1 to 5, 7, 8, 11
X, P	WO 93/19281 A	(ATLANTIC RICHFIELD COMPANY) 30 September 1993 see piston 70, Figure 3	1, 4, 5, 8

**Databases:** The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).